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ABSTRACT

Information intended for those concerned with the administration, planning, financing, operation, and maintenance of school facilities applies to both new and existing building. An examination of motivation and policies relating to energy conservation is followed by the methods used for quantitative assessment of energy savings relative to extra capital cost and operating personnel cost. Architectural decisions in designing new facilities that determine the basic energy-use patterns involved in operation are described. Available methods and equipment that can be used for energy conservation are identified. An assessment is made of available methods and equipment in terms of potential and usefulness in saving energy, first cost, reliablility, degree of complexity, and requirements for operating staff. (Author/MLF)

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Ministry of Education
Ontario

Hon. Thomas L. Wells
Minister of Education
1975

Energy Conservation for Schools

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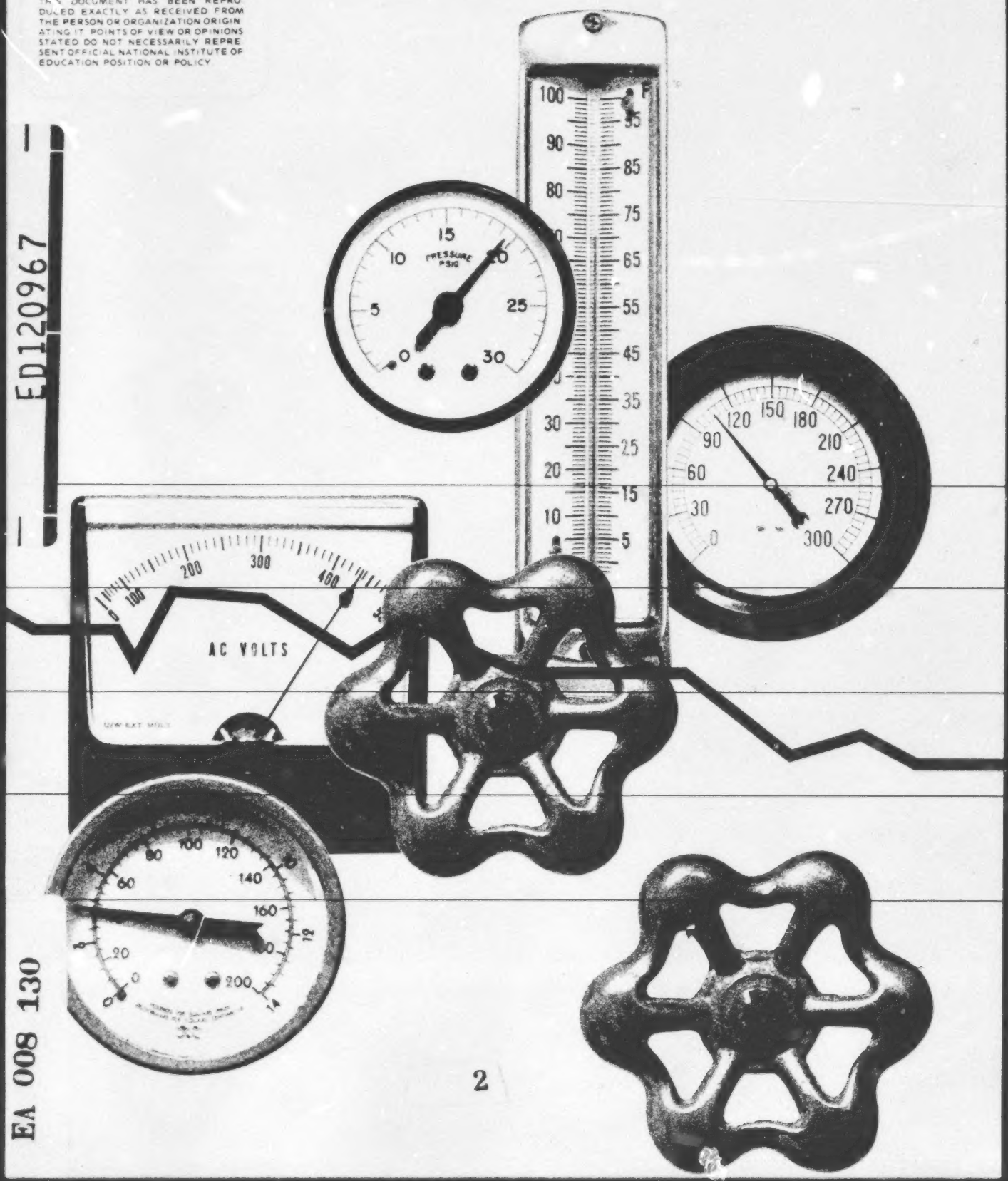

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Introduction

Buildings consume almost one third of the total energy used in Canada. The availability and supply of this energy is decreasing, while its cost is increasing rapidly. Moreover, the cost of energy will probably continue to increase. We must, therefore, make every reasonable effort to reduce the consumption of energy resources in our schools. If at the same time we can save money, we have an added bonus. All possible methods of achieving this aim should be examined, and those that promise a tangible return should be seriously considered.

The information contained in this publication applies to both new and existing school facilities and includes:

—an examination of motivation and policies relating to energy conservation;

—an examination of methods used for quantitative assessment of energy savings relative to extra capital cost and operating personnel cost;

—an examination of available methods and equipment that can be used for conservation of energy;

—an assessment of available methods and equipment in terms of potential and usefulness in saving energy, first cost, reliability, degree of complexity, and requirements for operating staff.

The information should prove useful to those concerned with the administration, planning, financing, operation, and maintenance of school facilities.

Motivation

If we continue to use our energy resources indiscriminately, artificial restrictions may be placed on their use. The less energy we use, the better our chance of finding new sources or additional supplies of existing sources before present supplies run out.

The rapidly increasing cost of energy should also motivate us to take a close look at our policies, criteria, and attitudes towards conservation. Buildings are designed differently on different continents, in different countries, even in different parts of the same country, and for good reasons: the cost of energy, the cost of labour, the cost of materials, the cost of capital, and the climate are different. It follows that the accepted standards of comfort and convenience are different.

It is possible that current standards exceed actual requirements and that one approach to energy conservation would be to re-evaluate our standards in the light of actual needs.

Policy

The development, refinement, and correct application of energy-saving methods and devices are the domain of the engineer and scientist. Beyond this, the choice and method is a matter of policy. Many perfected methods or devices conserve energy but involve additional first costs or extra skill and effort in the operation of the building. The decision as to what method to use depends upon various considerations. For a public body concerned with the construction and operation of buildings, it is a matter of striking the best balance between the short-term and long-term spending of public funds. This involves a critical re-examination of current policies and attitudes towards:

—criteria for capital cost of buildings;
—criteria for quality, involving the cost of operating and maintenance personnel;
—criteria for ventilation rates, lighting levels, personal comfort, and convenience.

How many energy leaks are there in your home? (school)

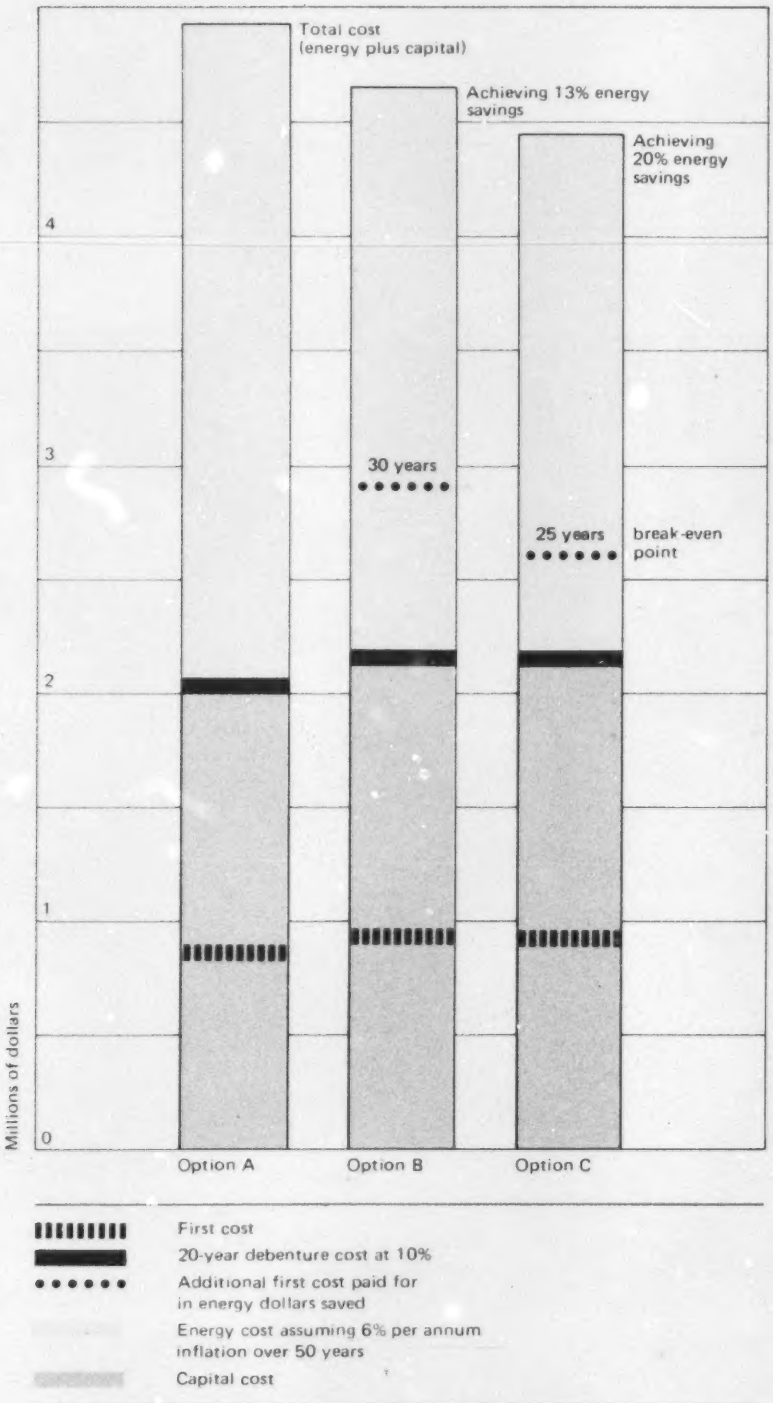
At one drop per second, a dripping hot water tap can waste about 175 gallons of hot water each month. The electricity required to heat that water would keep a 60-watt bulb burning continuously.

Poor insulation . . . a faulty heating system . . . inefficient use of appliances . . . all cause energy leaks in the home. This can increase the cost of running a home — and waste Canada's precious energy resources.

It makes good sense to use electricity and all forms of energy wisely. And that includes stopping those energy leaks.

Courtesy of Ontario Hydro

Cost



In evaluating the first cost of a building, both annual operating costs and energy consumption must be taken into account. Unfortunately, budgetary pressures often result in a situation where the first cost becomes the exclusive consideration. Schools built without any or with inadequate insulation in the walls and with inefficient equipment waste energy. Any evaluation of costs must include not only the first cost, but also the cost of energy, the cost of operation, the cost of maintenance, and the cost of replacing short-life equipment. Alternative systems must be evaluated on the basis of life-cycle costing.

The life-cycle cost of a piece of equipment is the amount of money that would have to be provided at the time the equipment is purchased – i.e., purchase price, cost of installation, plus the annuity required to cover the cost of operation for a specified "lifetime".

The data required to evaluate life-cycle costing are:
–initial cost (purchase price + cost of installation);
–lifetime of equipment;
–labour required for operation and maintenance, and estimate of cost of labour during lifetime;
–annual consumption of energy and other supplies, and forecast of costs for these items for the period;
–cost of capital;
–tax regulations that will apply;
–salvage value at the end of the period.

Life-cycle costing cannot be determined as precisely as first cost, but it provides a much better basis for making design choices.

The following list of criteria will favour progressively higher capital and operating personnel costs, but will also result in progressively lower energy consumption and/or cost:
a) lowest first cost;
b) lowest life-cycle cost at present energy rates;
c) lowest life-cycle cost at progressively increasing energy rates;
d) lowest life-cycle cost at progressively increasing energy rates, the increase in rates being different for the various sources of energy;
e) lowest life-cycle cost, including consideration of cost of replacing short-life equipment (usually at higher prices than when purchased);
f) least energy consumption but not lowest life-cycle cost.

When different systems with different initial costs, operating personnel costs, and energy consumption are considered, any one could become the first choice, depending on the criteria selected.

Life-cycle (longterm) costing of buildings[1]

For a building where the owner pays operating and maintenance costs as well as capital costs, there are three basic techniques for computing life-cycle (longterm) costs:

1. Cost/benefit analysis.
2. Time-to-recoup capital investment.
3. Life-cycle cost comparison.

Cost/benefit analysis formalizes the decision confronting an owner who must decide whether a capital improvement is economically justified. In more sophisticated applications, a cost/benefit analysis can also provide a rational basis for choosing among alternatives, after the go-ahead decision has been made.

Virtually every decision that one makes entails, at least subconsciously, some form of cost/benefit analysis. We are constantly balancing costs—in time, money, or effort—against benefits—in saved time, or simply in satisfaction. All costs and benefits must be reduced to a monetary value and the ratio computed. If benefits exceed costs, i.e., the benefit/cost ratio exceeds 1, then the project is economically justified.

The second method, *time-to-recoup capital investment,* merely calculates the time required to recoup the original capital investment through annual O&M savings, which are used to pay the annual debt service required to amortize a loan for the capital investment. If this time is less than the estimated useful life of the added building component, then obviously the investment is economically justified.

For *life-cycle cost comparison,* in its simplest method, one can simply reduce all costs to a total annual cost for the useful life of compared alternatives. Total annual cost (owning cost) comprises two basic categories:

1. Amortization (principal and interest) of capital cost debt, normally financed by bond issue.
2. Estimated annual O&M expenses.

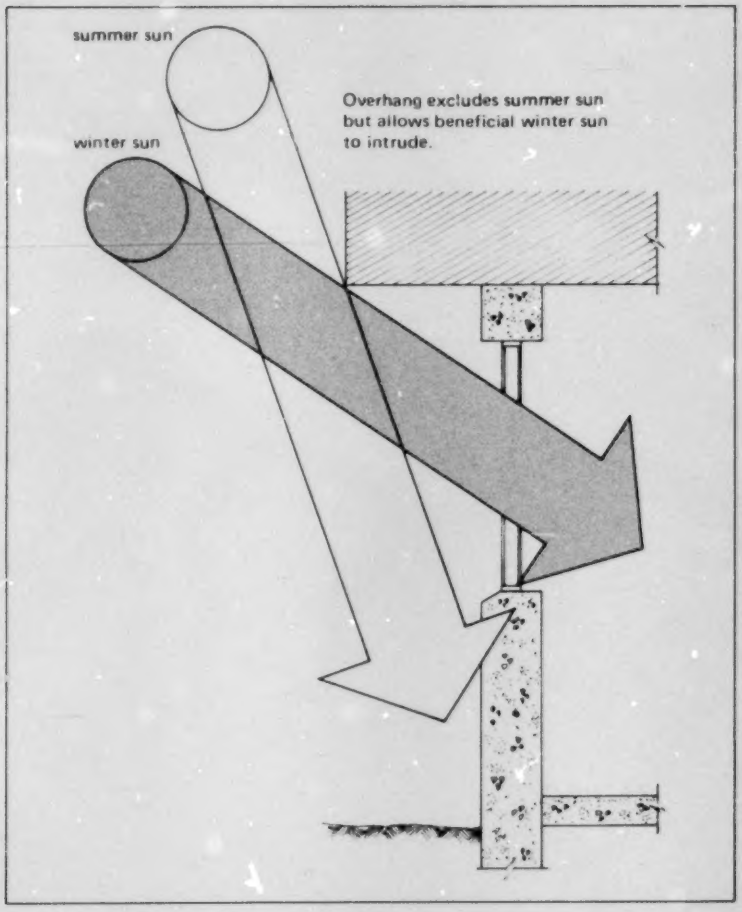
In the simplest case of comparing alternative systems, with equal useful lives, the lowest total annual cost is easily identified. But when the systems have different useful lives, the problem becomes more complicated. All costs must be reduced to the same useful life, and amortization costs reduced to a *uniform* annual level. Suppose, for example, that a central heating, ventilating, and air-conditioning system with 20-year useful life is compared with a packaged HVAC system with 10-year useful life. If the packaged HVAC system requires anticipated cost replacement of 70% of its originally installed equipment after 10 years, the annual cost of a capital recovery fund necessary to finance that cost over a 20-year useful life must be added to the basic amortization cost to equate comparative costs.

The most common error in life-cycle costing involves attempts to compare initial *cash* investment with annually paid *charges*. One cannot, for example, claim that a $100,000 cash investment is paid off in 10 years if it cuts O&M costs by $10,000 a year. At 9% interest, it takes more than 27 years to recoup that initial investment. Interest charges always apply, for the simple reason that borrowed money always carries a charge for its use, and unused, or saved money always carries the potential of earning interest.

In keeping with this principle, convert future savings to a "present-worth" basis. The "present-worth" concept reduces future savings to a common basis with current savings. This conversion is necessary because a dollar saved today is worth considerably more than a dollar saved some years from now. (At 9% interest, a dollar saved today is worth twice as much as a dollar saved 8 years from now.) The present-worth formula takes account of these future interest losses.

As a further means of insuring fair, consistent cost comparisons, reduce comparative costs for alternative systems to an annual basis. Even though a school board may treat operating and capital costs differently, such distinction must be ignored in analyzing what the school *should* do for longterm economy.

1. Educational Facilities Laboratories, *The Economy of Energy Conservation in Educational Facilities* (New York: Educational Facilities Laboratories, 1973), pp. 63-65. Reprinted by permission of the publisher.



Those concerned with the planning, administration, financing, and operation of school facilities should insist that energy conservation be an important feature of the design criteria.

Design decisions determine the shape of a building, the materials used in its construction, and the basic energy-use patterns involved in its operation, as well as the additional materials required to maintain or renovate it. A building cannot make optimum use of its energy resources unless it is designed to take advantage of natural elements. A basic design principle should be to complement, not ignore, the natural environment.

Shape
The building's shape will partly determine the energy required to heat and cool the building. Since heat gains and losses are transmitted through the walls and roof, the designer should attempt to minimize the surface area.

Site
Skilful exploitation of prevailing winds, topography and trees, a sheltered solar exposure, or other natural features may result in a less compact shape but will prove more efficient than a simple reduction in the surface area of the building.

In selecting a site, the impact of climate and microclimate is an important consideration. Where necessary, trees should be planted to provide shade, particularly on the east and west faces of the building.

Orientation
Generally, it is an advantage to locate a building so that its longest axis is aligned in an east/west instead of a north/south direction. The sun bakes east and west walls for longer periods and more ferociously than a south wall. Also, a south wall can be shaded more readily and intercepts solar rays at less direct angles, particularly in summer.

North-oriented building faces and windows should be reduced to a minimum. Entrances located on the north or west side should be protected from prevailing winds by man-made or natural barriers, earth berms, or trees.

Design

The following factors should be considered in the design of new construction:

1. The floor-to-ceiling height should be minimized to reduce the enclosed volume, to reduce the exposed surface area, and to make illumination more effective.

2. Spaces with a high internal heat gain should be located against the outside walls that have the highest exposure loss.

3. The disposition of space should be arranged so that ventilating air can be used in cascade—for example, from classroom to washroom to the outside.

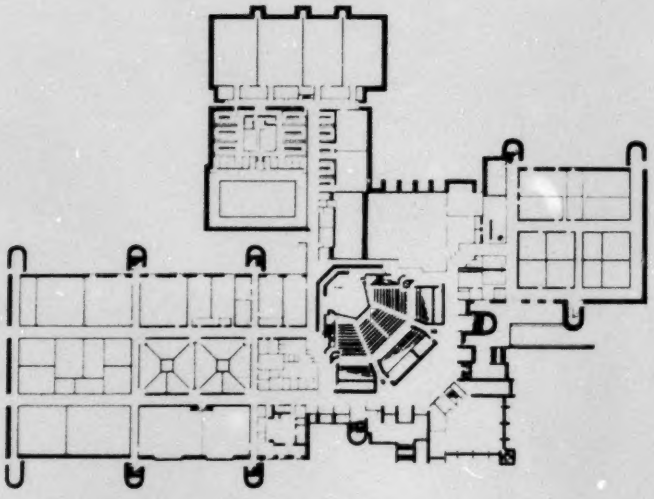
4. An open plan allows heat from the interior zone to transfer to the perimeter zone and exposed surfaces.

5. Window areas should be reduced to the minimum required for the occupants' psychological needs. A window/wall ratio might be as little as 10 per cent. This may also become an advantage for those spaces that require large amounts of storage and counter space—for example, a science laboratory.

6. All windows should be double-glazed.

7. Windows should be shaded from direct sunlight in the summer months and unshaded in the winter months if solar heat is an advantage.

8. A reflective coating may be used on either face of the inner glass of a double-glazed unit. This may reduce the "U" factor by 20 per cent.



Construction

1. Avoid the use of window frames that form a thermal bridge between the interior and exterior.

2. Use windows that are either permanently sealed or close to sealing gaskets.

3. Keep the exterior wall mass as high as practicable (weight of wall per square foot) and use the maximum amount of insulation. This will level out the peaking loads for heating and cooling.

4. Provide a vapour barrier to give a permeability of less than 0.15 perms.

5. Avoid "through the wall" mullions that provide a thermal bridge to the interior.

6. Avoid "through the wall" metal structural members.

7. Plan the construction sequence to avoid cracks and joints "through" the wall.

8. Insulate "slab on grade" floors with both vertical and horizontal perimeter insulation.

9. Locate insulation on top of the roof with the structural mass below. Make the roof mass as high as practicable.

10. Use "air locks" with two sets of doors at all building entrances and exits.

11. Keep areas around doors and windows, where cracks could develop, to a minimum.

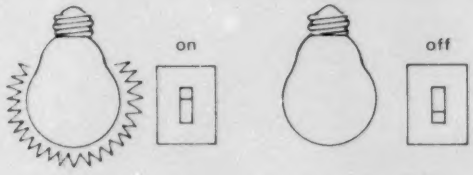
12. Use light colours in decorating interiors to increase the effectiveness of lighting.

13. Use as much mass as practicable in interior partitions and intermediate floors.

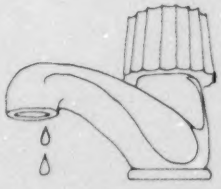
14. Use internal shades only when external shades are not practicable.

15. Choose building materials that require a minimum of energy to manufacture.

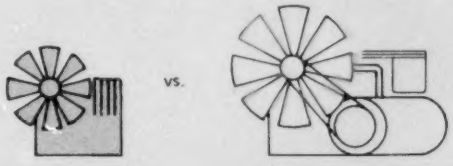
1. Use energy only when needed.



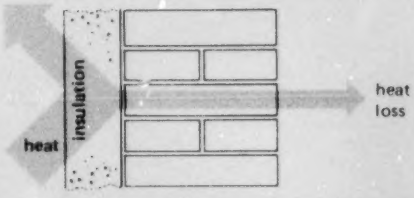
2. Maintain equipment adequately.



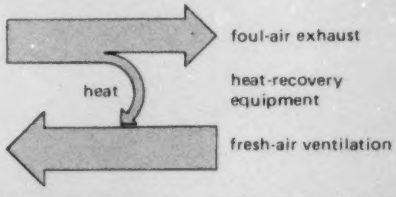
3. Use efficient equipment.



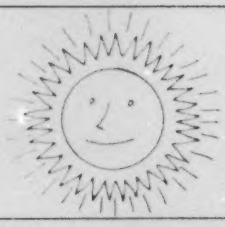
4. Minimize loads.



5. Recover waste heat.



6. Use more abundant energy sources.



The following recommendations cover most known energy conservation methods and strategies.

1. Manage plant so that it consumes energy only *when needed* and in amounts needed.

2. Eliminate waste of energy due to inadequate maintenance.

3. Reduce energy loads to a minimum, taking occupancy requirements and economic factors into account.

4. Use equipment and systems that utilize energy efficiently.

5. Recover waste heat.

6. Utilize the more abundant energy sources.

Operation and maintenance procedures will apply more to existing facilities. The choice of systems, load levels, and energy sources will apply more to new construction, although they could apply to an existing plant if retro-fitting, readjustment, and replacement of systems are considered.

Operation

Plant-operating procedures should be reviewed carefully so that opportunities for saving may be identified. This will involve devising an efficient timing system for the operation of the lighting, ventilation, and heating systems. Timing procedures for the "night-cycle" and the "weekend shut-down cycle" should be particularly precise and rigidly applied. The night and weekend cycle should incorporate a set-back of temperature to 15° C (60° F) during the heating season, the closing of all outside air dampers, and the shut-down of all exhaust fans.

Such timing cycles require the installation of automatic time clocks. In large schools a central monitoring and control console should be considered. More sophisticated centralized-control equipment allows the use of different cycles for various areas and facilities of the building and also allows relatively easy changes and adjustments to the timing cycles. Over-ride timers permit manual re-set "day cycle" for after-hours occupancy and return the control to the main time clock after a fixed number of hours. In small schools the automatic timing of the heating, ventilation, and lighting systems may

not be feasible or economical; maintenance and operating personnel should carry out such schedules manually.

The tightening of operating procedures is one of the simplest energy conservation measures; at the same time, it is one of the most effective and rewarding.

Further details relating to operating procedures and scheduling are given in the Appendix.

Maintenance

Inadequate maintenance, carried out in a sporadic, unorganized manner, results in excessive energy consumption. Proper maintenance saves both energy and equipment. Every board of education should charge a specific person with the responsibility of reviewing maintenance and operating procedures as they relate to energy conservation. Such a person may be the head of the plant maintenance department, providing he has adequate qualifications for the task. He should set himself definite goals, aiming for a reduction in energy consumption of, say, 20 per cent.

The board should institute a survey of the energy consumption of the schools in its jurisdiction. A questionnaire should be prepared asking for statistics on the monthly consumption of various forms of energy, as well as for data regarding size of facilities, population, use, and the type of heating and ventilation plant. Every such survey seems to yield a number of surprises. When the annual energy consumption of a group of very similar schools – all constructed in the same year in Toronto – was compared, it was found that some of them were consuming more than twice as much energy as others. A thorough check of the "problem" schools revealed maladjustment of controls, jammed outside-air dampers, and other similar maintenance problems.

Schools should institute programs designed to upgrade maintenance measures and personnel. Educational programs for plant personnel should draw attention to the energy crisis and outline the methods and procedures that may be employed to bring about energy savings. Personnel should be encouraged to take night courses at community colleges, and those who take them should be upgraded.

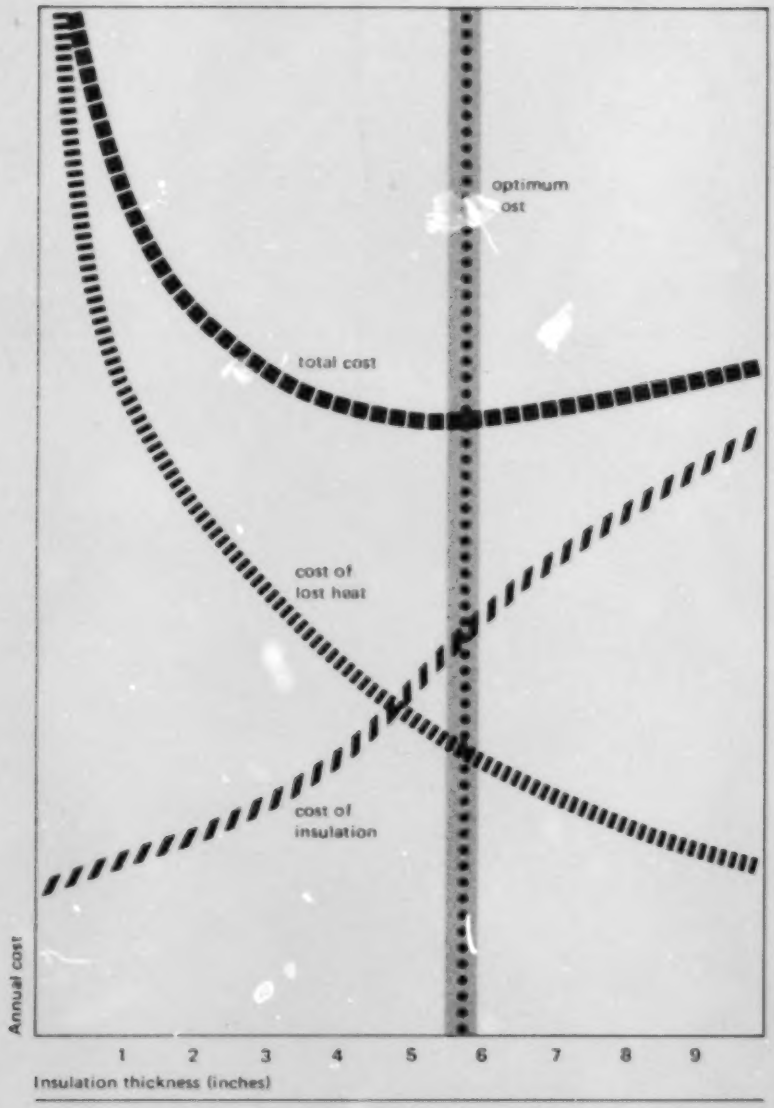
Improved renumeration should attract higher-calibre maintenance personnel. Money spent in this area should bring dividends and, in view of the increased cost of energy, may more than justify the extra expenditure.

Preventive maintenance will save energy. Particular attention should be given to systems that are most likely to cause excessive energy consumption through maladjustments or lack of maintenance. These include ventilation systems, boilers and their combustion systems, and automatic temperature-control systems.

For service of the more complicated equipment, contracts should be arranged with qualified outside firms. Maintenance personnel should have adequate maintenance manuals on equipment that they operate and maintain. For example, the control schedule of a unit ventilator, often used in heating and ventilation of classrooms, is a complicated mechanism; improper adjustments to the controls of the unit ventilator can result in excessive fuel consumption, freeze-ups, and other problems. Automatic controls for the central ventilation system can also be quite complex.

The effectiveness of such energy-oriented maintenance and operation programs can be assessed by actual experience. In one state in the U.S.A., such programs resulted in savings of 15 per cent in energy consumption. As it was estimated that only about 50 per cent of the schools fully carried out the programs, it would seem that savings of 20-30 per cent are possible.

Further details regarding suggested maintenance procedures are given in the Maintenance Checklist in the Appendix (see page 20).



The lowest combination of installed-insulation costs and heat-loss cost determines the thickness of insulation that is practical from the point of view of cost.

The heating, ventilation, lighting, and cooling loads of buildings should be reduced to the minimum levels that satisfy occupancy requirements. Every component of these loads should be carefully considered and its effect on energy consumption assessed.

Insulation

Rising energy costs more than justify increasing the amount of insulation in the school building. In estimating the economic benefits of insulation, one should include the savings in fuel, the decrease in the power consumption of circulating fans and pumps, and the reduced capital costs of the mechanical plant. The energy consumed by circulating fans can be quite substantial in forced-air heating systems.

The cost of providing insulation beyond the point of maximum economy is relatively small. Indeed, in providing extra insulation at such low cost it would be prudent to go beyond optimum economy in order to conserve more energy and to provide against future energy-cost increases.

With roof assemblies that require fire protection ratings, the maximum allowable thickness of insulation may be established by fire-rating tests. Added insulation may cause the structural steel to overheat and fail during a fire. Roof-venting is being investigated as a possible solution to this problem.

Infiltration

Infiltration of outside air represents a substantial portion of the total heating load of a building, often 30 to 50 per cent. The infiltration properties of the building skin generally do not receive as much scrutiny and attention as the heat transmission or insulation properties. One reason for this is that the infiltration data for various building materials cannot be as accurate as the heat conduction data.

For the energy-oriented designer, the choice of building skin components should depend as much on infiltration properties as on conduction properties.

Ventilation

Mechanically-induced ventilation is normally used during the hours of occupancy. At such times ventilation may represent the largest single component of the total heating load; therefore, considerable care must be exercised in selecting the amount of outside air to be used, the design of the ventilation system, and the arrangement of its controls.

The minimum ventilation rates recommended by the American Society of Heating, Refrigeration, and Air Conditioning Engineers should be applied. Since it is neither the depletion of oxygen nor the build-up of carbon dioxide but the dilution of objectionable body odours that governs ventilation requirements, the recommended rates are approximate and are stated with some latitude. The required amount of ventilation depends on room volume per occupant; the prevailing dietary and hygienic habits of the occupants; the type of activity conducted; and the amount of air being recirculated if such air passes through water sprays, cooling coils, and filters. When using these recommendations, one should clearly understand what is meant by the suggested ventilation rates. They do not always refer to the amount of air indicated by the damper setting in the central ventilation unit; nor do they necessarily refer to the amount of air that has to enter the room through the mechanical ventilation system. What they indicate is the amount of odour-free, non-contaminated air that needs to be provided.

Natural infiltration can provide a substantial amount of ventilation in cold weather. This is borne out by actual experience in many schools. Automatic controls in some schools are arranged to close all fresh-air intakes at −1° C (+30° F) or lower outside air temperatures.

In schools with central ventilation systems, fresh air should be provided on the basis of the number of occupants. One should not make the error of assuming that the same people can be everywhere at the same time, in classrooms, in the general purpose room, cafeteria, and gymnasium. In addition, a central recirculating ventilation system increases the effective volume of air per occupant as it recirculates and mixes air from unoccupied spaces.

Air should not be recirculated from certain areas of the school, such as washrooms, change rooms, locker rooms, kitchens, and shops where welding or similar work is being performed. Separate fresh-air supply systems for such areas should be avoided; make-up air should be taken from other areas of the building or from the central ventilation system. Rather than being ejected directly into the atmosphere from classrooms, the air should be allowed to pass to areas that need to be exhausted without recirculation. In this way the outside air required for the ventilation of classrooms will do double duty. Also, by means of such transferring of air, the total amount of outside air required for the building can be reduced.

Ventilation systems should be designed in such a way that it should not be necessary to ventilate the whole building when only part of the building is in use. It may be desirable to provide a separate ventilation unit for the auditorium or other similar spaces that may be used by the community after regular school hours.

Lighting

Much of the electrical energy consumed in our schools can be traced to lighting. Even in schools with air-conditioning, lighting uses approximately 50 to 60 per cent of the electrical energy. Every watt of lighting necessitates more than another watt of energy in refrigeration, pumps, and fans. In non-air-conditioned schools, excessive lighting will contribute to overheating in mild weather. Perhaps it is time to reassess present lighting standards with a view to conserving energy.

Lighting design should stress quality rather than quantity. With careful design and the use of efficient luminaries, the necessary lighting levels can be achieved with lower wattage. Over-lighting should be avoided, particularly in auxiliary areas such as lobbies, corridors, storage rooms, and similar spaces. Lighting in such areas should be reduced to the lowest levels that safety and security will allow.

Choose colours that reflect light. Keep walls and ceilings clean. Dark colours and dirt reduce illumination by as much as 40 per cent.

Consider installing a number of separate lighting circuits or dimmers in areas where high levels of lighting are needed only periodically.

One of the best economy measures is to turn off the lights when a room is not in use.

Mechanical Systems

The type of mechanical system selected, its size, and the type of equipment it uses affect the energy consumption of a building. Mechanical systems for educational facilities should have a high energy-utilization efficiency. The inclusion of waste-heat recovery devices should be carefully considered. Systems with high transportation energy requirements should be avoided.

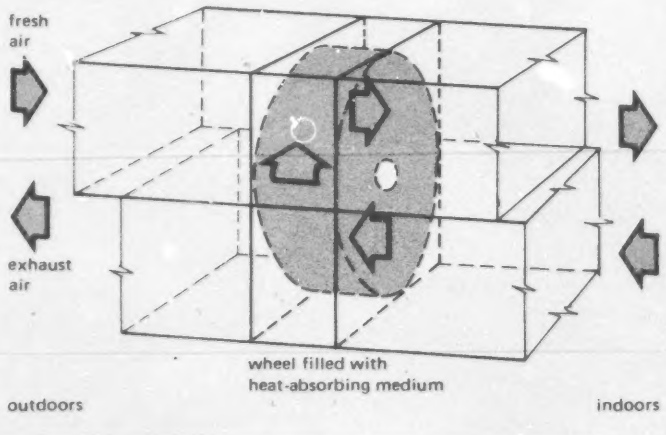
Efficiency

Fans and pumps should be chosen for maximum efficiency. The more efficient equipment usually requires less horsepower for operation, and thus can result in a sizable saving in energy, as much of this equipment operates 24 hours a day. Systems chosen for maximum efficiency may at times involve larger and more expensive equipment.

Air ducts and water pipes should be sized to reduce the friction losses of a system. This may involve increased building space requirements. Air filters should be chosen for their ability to reduce friction losses and yet maintain high filtration efficiency.

In cooling systems, the opposing requirements of lower air quantities and higher chilled water or refrigerant temperatures should be resolved to arrive at the optimum energy requirements. Refrigeration systems should be selected for the least power-to-highest-cooling-effect ratio. Air-cooled equipment is not efficient in this regard, and thus should be avoided where possible.

Rotary Air-to-air Heat Exchanger



The use of air-conditioning systems such as terminal reheat, multi-zone, and dual duct should be carefully studied, as they involve simultaneous heating and cooling and may use extra energy.

Temperature control zones should be sized to avoid over-heating or over-cooling. Each area of the building that has distinct heating or cooling requirements – due to varying population loads, solar loads, lighting loads, or other heat-producing equipment loads – should have its own thermostatic control.

The efficiency of a system will also depend on the functioning of automatic controls. Automatic control systems should be simple, reliable, and easy to operate.

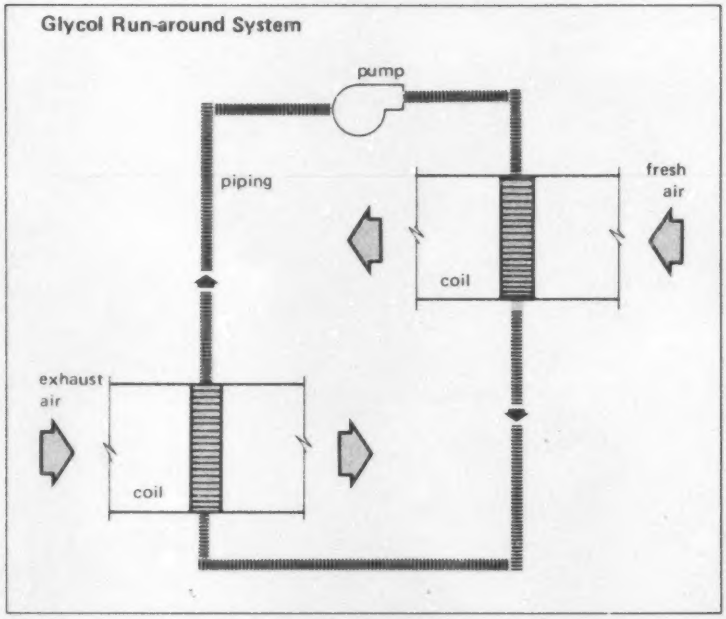
Recovery

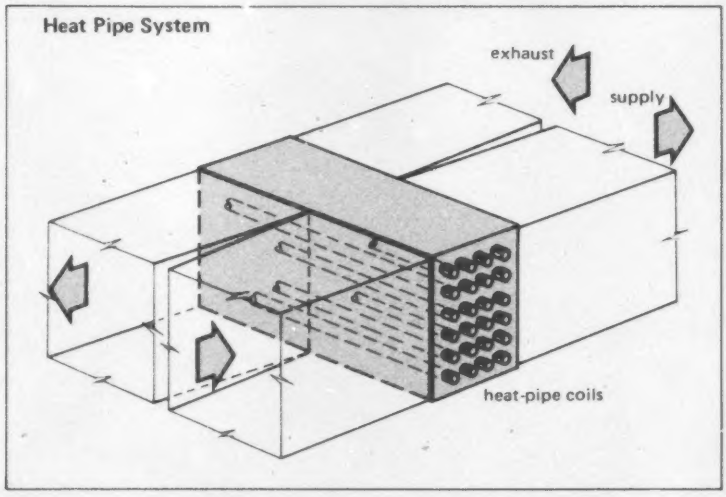
The ventilation systems of most buildings exhaust large quantities of heat and moisture. Heat-recovery devices extract much of this heat and moisture from the exhaust air to be reused.

1. *Rotary Air-to-air Heat Exchanger*

This is a revolving cylinder packed with a coarsely knitted metal mesh. As the cylinder rotates, adjacent streams of exhaust air and incoming replacement air pass through it. The cylinder gathers heat from the warm exhaust air stream and deposits it in the incoming cold air stream. Some rotary heat exchangers contain a material that also enables them to pick up moisture. Thus, the incoming cold air stream is simultaneously heated and humidified. Rotary exchangers recover between 60 and 80 per cent of the heat in the exhaust air stream which would otherwise be wasted.

The installation of rotary heat exchangers generally requires additional ductwork and building space, as both the exhaust ductwork and the make-up air ductwork must be brought to the location of the rotary exchanger. Fans require additional horsepower to overcome the air friction in the heat exchanger. Precautions must be taken to prevent freeze-ups due to condensation of the exhaust air in cold weather.





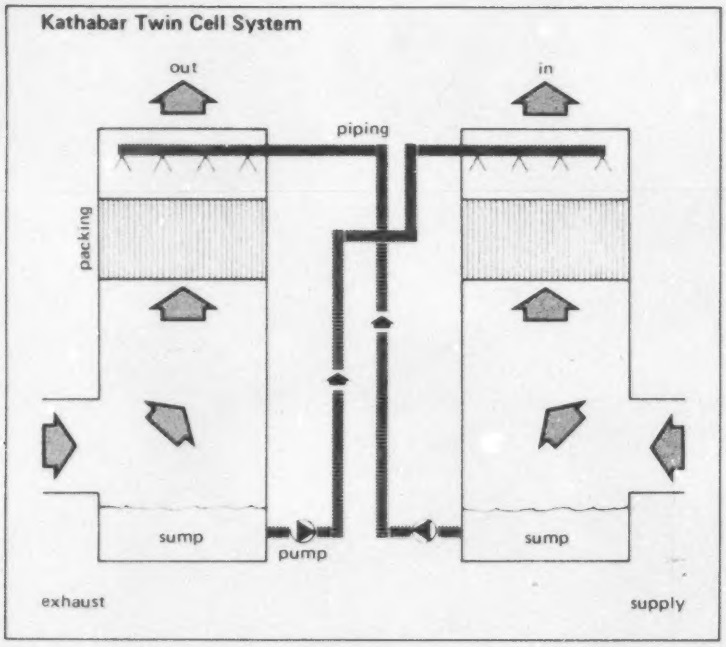
2. *Glycol Run-around System*
This consists of two coils, interconnecting piping, and a pump. One of the coils is located in the exhaust air stream, while the other coil is located in the incoming outside air stream. A glycol-water mixture is heated in the coil in the exhaust air stream, then pumped to the other coil, where heat is given up to the incoming cold air stream.

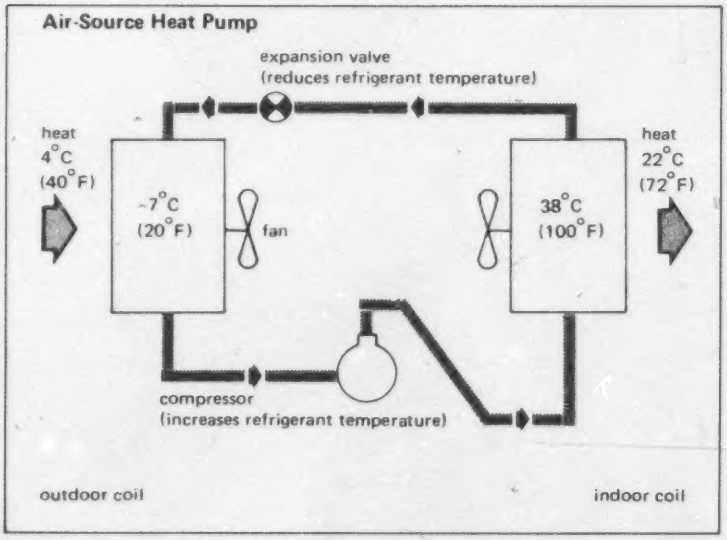
A glycol run-around system cannot add moisture to the incoming air stream, and its heat-recovery efficiency is lower than that of a rotary heat exchanger. However, with this system the exhaust air stream and the incoming fresh air stream can be located at some distance from each other. Also, the moving component of the system is a circulating pump, which is a simpler device to maintain and operate.

3. *Heat Pipe System*
This system has no moving parts; it consists essentially of a bundle of horizontal, super-conducting heat pipes. Exhaust air passes over one end of the heat pipes, while the outdoor make-up air passes over the other end. The tubes are usually equipped with external fins to improve the air-side heat transfer. Inside each heat pipe there is a wick and a working fluid from the wick. The evaporated vapour flows to the cold end of the pipe, where it condenses and returns through the wick to the hot end as a liquid. In terms of efficiency, the heat pipe system lies somewhere between the glycol run-around system and the rotary heat exchanger. Ductwork arrangement and space requirements are similar to those for a rotary heat exchanger. A heat pipe system cannot add moisture to the incoming air stream.

4. *Activated Charcoal Filters*
Charcoal filters aid heat recovery in an indirect way, as they reduce the fresh air requirements. As air passes through such filters, odorous gases and vapours are absorbed. Since most of the odours are eliminated from the air, a lesser quantity of fresh outdoor air is required.

Once the activated charcoal has absorbed its total holding capacity, it must be replaced by new charcoal to maintain continuous air purification.





5. *Kathabar Twin Cell System*
This system involves open sprays of a hygroscopic fluid. Fluid is pumped from the sprays in the exhaust air stream to the sprays in the make-up air stream and vice versa. Thus both heat and moisture can be exchanged.

The heat-recovery efficiency of this system is about 65 per cent. One advantage is that supply and exhaust ductwork can be widely separated. In this respect, it is similar to the glycol run-around system.

6. *Heat Pumps*
Normally heat flows naturally from a region of high temperature to a region of low temperature. Devices that reverse this natural direction and cause the heat to flow from a region of low temperature to a region of high temperature are termed *heat pumps*. Heat pumps require driving power to push the heat "uphill". The most familiar type of heat pump is the air conditioner, which pumps the heat from the cool indoors to the hot outdoors. Generally, however, the term *heat pump* is applied to a device that provides a beneficial heating effect.

External-source heat pumps take their heat from an exterior source such as air, water, earth, or solar radiation. Their efficiency depends on the temperature of the source of heat.

Air is the most readily available source of heat, but it has the disadvantage of being at its lowest temperature when most of the heating is required. For this reason, air-source heat pumps are not economical at very low temperature. The outdoor air coils of such heat pumps require periodic defrosting.

Water can be a very satisfactory source of heat, providing that it is available in abundant quantity and is not overly corrosive. This will generally apply to locations immediately adjacent to lakes, large streams, or an ocean. There are instances where well water has been used successfully for this purpose.

Earth as a heat source involves a great number of buried coils and therefore considerable first cost. Generally, its heat-transfer properties cannot be predicted with sufficient accuracy and vary greatly with moisture content, compaction, and soil type. Leaks in buried coils may be difficult and expensive to locate and repair.

Solar radiation has the basic advantage that it is available at relatively high temperature even in very cold weather. Solar radiation is picked up by solar collector panels, which generally consist of pipe coils facing the sun and protected from the low outdoor temperatures by glazing. Water or some other fluid is pumped through the coils, where it picks up solar heat. The heat pump then pumps the solar heat up to the temperatures required by the heating system. Solar heat-source systems generally involve a means of storing the heat for use during the night and other periods of insufficient solar radiation.

Larger buildings may have interior areas that require cooling during both summer and winter. The cooling of such interior areas in cold weather is generally accomplished by means of increased ventilation with outdoor air.

Internal-source heat pumps can be used for cooling the interior areas and at the same time providing heat for other areas. Internal-source heat pumps can be quite efficient, as the unwanted heat of the interior zones is always available at a constant room temperature. Thermal storage, or heat storage tanks, can be used with internal-source heat pumps to further increase the amount of heat recovered. In mild weather the amount of heat available from the interior zones will exceed the amount of heat required for heating the exterior zones. This excess of heat can be stored during the day in a thermal storage system for use during the night when no heat is available from the interior zones.

Thermal storage systems can also be used to relieve the loads carried by the heating or cooling systems during peak periods in winter or summer. This measure may in turn reduce the maximum capacities required of the heating or cooling plants as well as the costs that usually result from peaks in energy demand.

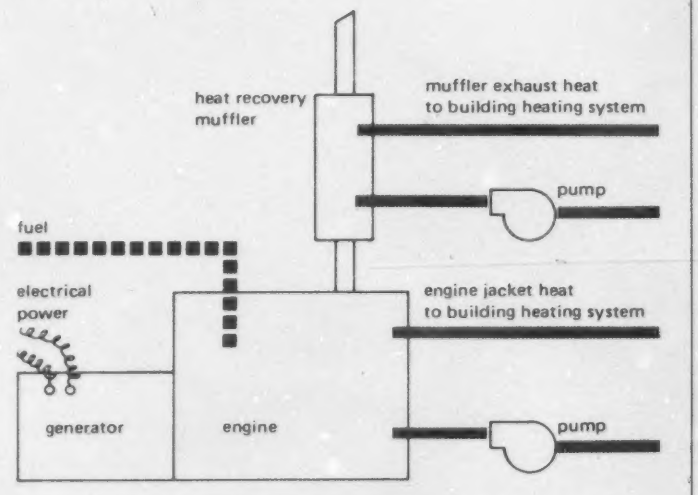
7. *Multiple Heat Pump Systems*
Heat can be recovered from areas requiring cooling and transferred to areas requiring heating by means of several heat pumps interconnected with a piping loop in which water is circulated. In such a system, heat pumps on the cooling cycle reject heat into the piping system, while heat pumps on the heating cycle extract heat from the piping system. At the times when the overall heat balance of the building is such that a net heat addition is required, such heat is added to the common piping loop. At other times heat is removed from the piping loop by means of cooling towers. Such a system can be efficient in a building that has simultaneous demands for heating and cooling in various zones of the building.

8. *Total Energy Systems*
The generation of electrical power always produces waste heat as a by-product. Thermal electric generating plants normally reject such waste heat into the adjacent lake or the atmosphere. A total energy plant in a building generates electrical power at the building site and utilizes waste heat for internal heating, cooling, or heating of domestic water, or stores it for later use.

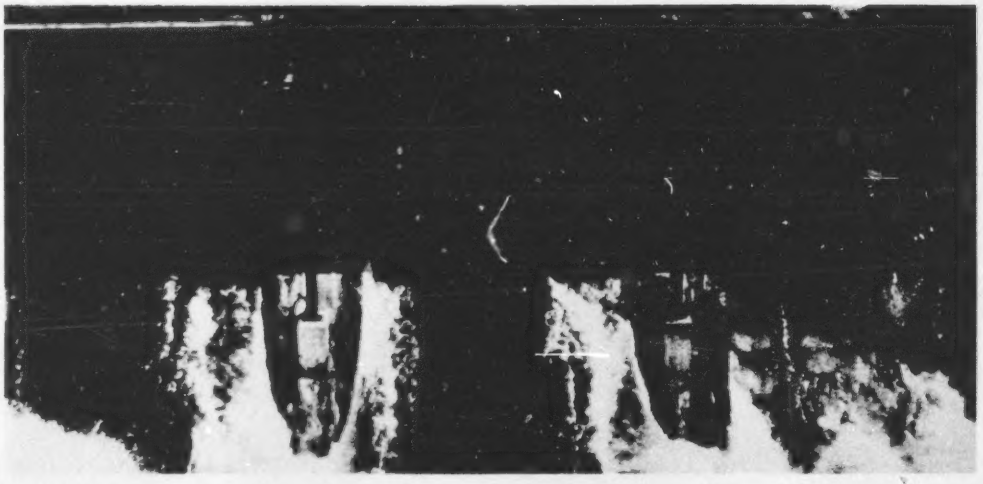
At the times when demands for electricity and waste heat match, such plants are very efficient. At other times the recovered heat cannot be fully utilized or must be supplemented by conventional burning of fuel.

Total energy systems have been successfully employed in larger educational facilities. Their drawbacks are high initial cost, complexity of system, and increased maintenance requirements.

Total Energy System



Sources

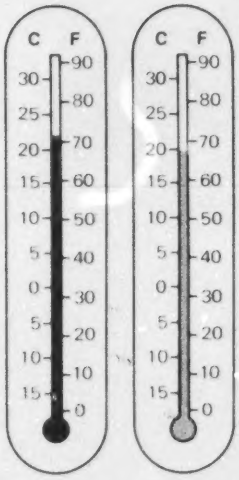


In considering a practical energy source for a building, the choices available are rather limited. Electricity is used for lighting and for powering fans, pumps, etc. For heating, either electricity or a fossil-derived fuel such as gas, oil, or coal is used.

Electricity is derived partly from fossil fuels, partly from a renewable hydro source and the more abundant source of atomic energy. A building with an efficient combustion device will utilize the fossil fuels better than the central thermal electric plant. This is due to the generally low efficiency of any thermal device producing power rather than heat. On the one hand, it can be argued that electricity is derived from the more abundant sources of energy, while on the other hand it can be shown that central thermal electric plants are less efficient in utilizing fossil fuels.

The more exotic sources of energy are not likely to be employed by a school directly, although this may change with time and developing technology. Such sources include solar energy, wind power, geothermal energy, and energy derived from solid wastes. Central utilities can utilize such sources more readily.

Recommendations



Save energy by lowering temperatures

Existing Plant

In existing buildings, the more practical energy-conservation measures consist mainly of upgrading the operation and maintenance procedures. This should include a review of the original design criteria for the mechanical and the electrical systems. One should look carefully at the possibility of reducing the ventilation rates, lighting levels, space temperatures, and humidity levels. It is generally possible to reduce the minimum fresh-air settings of unit ventilator systems and the central ventilation systems. Tubes can be removed from lighting fixtures in non-essential areas such as corridors, storage rooms, basements, etc. In some cases, tubes can be removed in working areas such as offices and classrooms. More care is required in such locations, as non-uniform lighting will result with some fixture layouts.

Modernization or retro-fitting of existing buildings should be considered with a view to effecting savings in energy consumption. It is unlikely, however, that extensive retro-fitting will prove economically justifiable. The first cost of alterations is always higher than that of new construction. Also, the remaining (and often relatively short) life of an existing building does not warrant spending large sums on upgrading. Opportunities for modernization will arise from the need to replace worn-out boilers, burners, and other equipment.

On the other hand, some low-cost improvements may be economical, such as insulating bare heating pipes and steam pipes, adding time clocks for lighting and ventilation systems, adding a night set-back feature to temperature controls, and rewiring classroom lighting to allow switching off of fixtures adjacent to windows. The economic validity of more expensive improvements, such as adding insulation to existing walls, double-glazing, and installing waste-heat recovery equipment, should be investigated.

New Construction

Some energy-conservation measures for new construction do not involve extra capital cost, and most of those that do can be justified economically on the grounds of reduced annual operating costs. Some energy-conservation measures, however, will not be justifiable economically. Energy conservation in new construction requires a review and reassessment of the present methods for setting first-cost priorities for projects. Extra capital expenditures may be justified in cases where economic and energy-saving advantages can be shown for the life cycle of the building.

The establishment of energy budgets and minimum construction standards should be considered. An example of such a set of guidelines is *Energy Conservation in New Building Design, Standard 90-p,* prepared by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (A.S.H.R.A.E.).

Before selecting a mechanical or electrical system or sub-system, the amount of insulation, and amount or type of glazing, designers should be required to investigate and compare two or three alternate systems with regard to cost and energy consumption for the life cycle of the building.

Appendixes

Operation Checklist

1. Ensure that operating personnel are familiar with equipment, installations, and distribution systems.

2. Make available pertinent drawings and operating instructions to operating personnel.

3. Develop schedules and instruct cleaners, guards, and other workmen to turn the lights on in the morning and off at night at predetermined times.

4. Schedule control and switching off of street area, perimeter, and floodlighting.

5. Determine the most economical use of snow-melting and heating-cable systems in accordance with weather conditions.

6. Investigate the possibility of rescheduling operations in order to decrease the peak loads on utilities.

7. Develop a building heating schedule to allow the most economical use (i.e., the most advantageous turning "on" and "off" points) of steam, hot water, and electric heating.

8. Investigate humidity systems for proper operation and adjustment.

9. Shut down motor-operated equipment whenever possible to reduce power consumption.

10. Shut down air-conditioning and ventilating systems (whenever possible) after working hours and during weekends and holidays.

11. Lower storage tank temperatures of domestic hot water heating systems to the point where the storage capacity is just sufficient to meet the occupancy requirements.

12. Check calibration of controls for air-conditioning systems and boilers to ensure the most effective performance.

13. Set back thermostat controls to 15°C (60°F) for night-time operation.

14. Place lamps to give the desired illumination at task stations and reduce lighting levels in non-essential areas.

15. Check that all plumbing fixtures are turned off when not in actual use.

16. Keep accurate records, properly tabulated and supplemented with graphs. They should include:
—consumption of fuels, water, and electricity;
—production of steam where steam is being generated;
—changes in operating procedures (e.g., changes in scheduling equipment shutdown, adjustments, etc.);
—inspections;
—modifications and improvements pertaining to energy savings and related installation costs.

The records should show changes in energy consumption resulting from the implementation of the energy-conservation program. An evaluation of savings should be based on the annual meteorological records. A summary of fuel and electricity consumption for each year should be prepared.

17. Monitor flue gases on a regular basis to ensure optimum combustion.

18. Develop specifications for new equipment to ensure that it is designed to use the minimum amount of energy within the requirements of performance, longevity, and maintenance.

19. Do not buy inexpensive and inferior equipment to save money on the initial cost. More often than not, inferior equipment consumes more fuel or electricity.

20. Consider installing monitoring devices on equipment that uses large amounts of energy. The monitoring device will sound an alarm or shut down improperly maintained equipment until the malfunctions are corrected.

21. Institute an educational program for operating staff relating to the conservation of energy.

Maintenance Checklist

1. Establish a controlled preventive maintenance program.

2. Clean lighting fixtures and replace light bulbs and fluorescent tubes regularly.

3. Consider institution of group relamping programs.

4. Check air filters of ventilation and air-conditioning systems.

5. Maintain equipment to allow operation at optimum efficiency.

6. Clean all equipment regularly.

7. Enter into maintenance contracts for specialized systems such as controls, refrigeration equipment, water treatment, etc.

8. Conduct combustion efficiency tests at regular intervals and make any necessary adjustments.

9. Weather-strip windows and door openings, caulk window and door frames, and instal storm windows.

10. Provide insulation, where feasible, for roofs, walls, ceilings, and floors.

11. Seal all sky-lights and other roof openings as tightly as possible to reduce the "chimney-effect".

12. Improve insulation of steam mains, risers, runouts, etc. Add insulation to all uninsulated pipe fittings, flanges, and equipment.

13. Check radiation surfaces for obstructions.

14. Remove or shut off unused steam and return piping of steam distribution systems.

15. Check hydronic systems for the proper temperature difference between supply mains and return mains.

16. Examine air distribution ducts for leaks, deterioration, separation of insulation, heat pick-up from pipes, and required insulation improvements.

17. Check insulation on refrigeration lines.

18. Instal raw water make-up supply meters in boiler plants.

19. When replacing electrical fixtures, use more efficient fixtures wherever possible, taking into consideration the efficiency of lamp sources and fixture design.

20. Investigate and correct the power factor of the electrical distribution system.

21. When alterations are being made, evaluate the light reflectances of walls, floors, and ceilings to achieve more efficient light utilization.

22. Add automatic controls wherever possible to allow the most economical operation of equipment.

23. Instal clocks, photo-cells, and other controls to ensure the predetermined cycle operation.

24. Revise electrical circuits to allow partial switching of electrical loads.

25. Add zone controls, day-night controls, mixing temperature controls, return controls, return-air temperature controls, etc., as required, to reduce energy consumption.

26. Investigate the feasibility of installing air-to-air and air-to-water heat-recovery equipment in systems requiring large volumes of outside air.

27. Consider having a competent combustion engineer make a flue gas analysis at least once a year to properly adjust the fuel input and to check combustion.

28. Institute educational programs relating to the conservation of energy for maintenance staff.

Forms

The following forms have been developed to assist individual schools and school boards in monitoring and assessing their energy requirements and consumption. It is hoped that these forms will become standard so that it should be possible to make comparisons across the Province of Ontario.

For those boards who use the energy consumption analysis form the number of degree days is quite important. A *degree day* is a standard measure used by heating engineers to measure the heating season's coldness. The number of degree days in a calendar day is determined by substracting the day's average from 65°F (18° C). If the high on a given day was 60°F (15°C) and the low was 40°F (4°C), the average temperature that day would be 50°F (10°C). Subtracted from 65°F (18°C), this would give 15 degree days for that calendar day. No degree days are counted when the mean temperature is above 65°F (18°C).

The table below[1] gives the average monthly and yearly degree days for some Ontario towns and cities. Degree days for locations not shown should be obtained from the nearest meteorological office.

1. While it is recognised that conversion to the metric system is already underway, it is felt that the hardware for recording purposes will not be readily available for some time. Calculations and recording of energy consumption should therefore continue to be made in Fahrenheit degrees.

Location	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*Yearly total*
Belleville	19	47	168	499	840	1277	1420	1266	1104	651	322	96	7709
Chalk River	31	96	270	620	984	1528	1717	1477	1280	756	372	105	9236
Cochrane	96	180	405	760	1233	1776	1978	1701	1528	963	570	222	11412
Goderich	53	71	183	502	852	1190	1308	1203	1119	699	409	123	7712
Huntsville	50	102	231	570	945	1411	1553	1379	1234	750	384	117	8726
Kapuskasing	133	200	432	736	1211	1805	2034	1732	1523	949	585	256	11596
Kenora	55	93	367	685	1230	1788	2012	1677	1409	852	479	173	10820
Kingston	19	40	147	481	831	1287	1451	1297	1113	654	329	75	7724
Kirkland Lake	115	174	384	760	1197	1783	1965	1681	1522	963	533	192	11269
Kitchener	16	59	177	505	855	1234	1342	1226	1101	663	322	66	7566
London	24	43	187	469	816	1215	1350	1210	1060	631	343	94	7442
Moosonee	177	208	447	806	1284	1885	2173	1848	1690	1125	735	345	12723
North Bay	74	119	328	632	1027	1545	1736	1492	1316	814	460	167	9710
Orillia	37	90	207	536	903	1342	1504	1362	1218	768	391	105	8463
Ottawa	20	54	232	536	911	1442	628	1409	1187	681	336	85	8521
Owen Sound	50	68	189	487	822	1215	1352	1232	1128	711	394	114	7762
Parry Sound	40	81	207	536	897	1349	1510	1362	1231	744	394	129	8480
Port Dover	31	47	132	446	777	1135	1262	1144	1026	645	332	69	7046
Sarnia	31	34	141	425	774	1138	1243	1158	1023	645	353	96	7061
Sioux Lookout	37	121	384	750	1293	1832	2027	1720	1497	930	518	204	11313
St. Catharines	3	28	108	394	726	1088	1187	1096	986	597	285	39	6537
Sudbury	58	105	316	620	1020	1525	1752	1509	1345	813	451	152	9666
Thunder Bay	91	136	381	682	1120	1618	1843	1587	1360	856	547	247	10468
Toronto	8	17	141	405	730	1118	1261	1119	988	588	304	65	6744
Windsor	6	16	122	378	751	1123	1254	1100	947	543	264	56	6560

Daily Energy Consumption Readings

School:

Address:

Month: 19

Date	Electricity			Oil	Gas	Water	Remarks: Note any unusual factors affecting energy requirements (type and duration of after-hour activities, equipment breakdown, power failures, etc.)
	demand kW	maximum demand kW	meter reading kW·h	gal.	100 cu. ft.	100 gal.	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
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29							
30							
31							

Instructions:

1. Ensure that month and year of this record are noted.
2. Take readings at the same time each day (including Saturdays, Sundays, and holidays when building is occupied, if feasible.)
3. Enter readings in *all* applicable columns.
4. When reading electrical demand meters, note that the red needle indicates "demand" and the black needle indicates "maximum demand".
5. Electrical, gas and water consumption are read from dials, left to right, and should be recorded to the nearest whole number. Do *not* calculate consumption in the preceding 24-hour period, but record the cumulative total each day as read directly from the dials.
6. Similarly, oil readings should be taken directly from the dial. Oil reading figures will decrease since the dial indicates the number of gallons remaining in the tank. Do *not* calculate the actual consumption.

Energy Consumption Analysis

School:

Address:

Board of Education:

Gross floor area: Sq. ft.: Year:

Month:	Electricity			Oil			Gas			Water			Total utilities cost
	$	kilowatt hours	kW.h sq.ft.	$	gallons	btu sq.ft.	$	1000 cubic ft.	btu sq.ft.	$	1000 gallons	gals. sq.ft.	
Jan.													
Feb.													
Mar.													
Apr.													
May													
June													
July													
Aug.													
Sept.													
Oct.													
Nov.													
Dec.													
Total													

Month:	Degree days	Costs per sq. ft. (¢)					Costs/sq. ft./d.d. (mills)					btu's/sq. ft./d.d.				
		elec.	oil	gas	water	total	elec.	oil	gas	water	total	elec.	oil	gas	water	total
Jan.																
Feb.																
Mar.																
Apr.																
May																
June																
July																
Aug.																
Sept.																
Oct.																
Nov.																
Dec.																
Total																

Remarks:

Further Reading

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This entire issue is devoted to the topic of energy and contains much relevant material in addition to the feature article mentioned above.